Cross-validation of pedometer-determined cut-points for healthy weight in British children from White and South Asian backgrounds

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Running Head: Cross validation of pedometer-determined cut-points

Abstract

Background: Evidence-based pedometer cut-points for health have not been sufficiently examined in the context of ethnicity.

Objective: To: (1) evaluate previously described steps/day cut-points in a sample of White and South Asian British primary school children and (2) use ROC analysis to generate alternative, ethnic specific, steps/day cut-offs for children.

Methods and procedures: Height, body mass and pedometer determined physical activity were assessed in 763 British children (357 boys and 406 girls) from White (n = 593) and South Asian (n = 170) ethnic groups, aged 8-11years.

Results: The Vincent and Pangrazi (2002) cut-points significantly predicted BMI in white (P = .006, Adjusted R^2 = .08) and south Asian children (P = .039, Adjusted R^2 = .078). The Tudor-Locke et al. (2004) cut-points significantly predicted BMI in White children (P = .0001, Adjusted R^2 = .079) but not South Asian children (P < .05). ROC analysis indicated significant alternative cut-points in White and South Asian boys and girls (all P = .04 or better, Adjusted R^2 = .091 for White and .09 for South Asian children). Subsequent cut-points associated with healthy weight, when translated to steps/day were 13,625 for White boys, 13,135 for White girls, 10,897 for South Asian boys and 10,161 for South Asian girls.

Conclusions: Previously published steps/day cut-points for healthy weight may not account for known ethnic variation in physical activity between White and South

Asian children in the UK. Alternative, ethnic-specific, cut-points may be better placed to distinguish British children based on pedometer determined physical activity.

Keywords: Overweight, Obesity, Ambulatory Physical Activity, Ethnicity

Introduction

The beneficial effect of habitual physical activity on health in children and young people is well established (Wedderkopp et al., 2003) and increasing the proportion of children who are physically active has become an important public health priority to combat the burden of diseases associated with lack of activity (Clemes and Biddle, 2013). The accurate measurement of physical activity in children and young people is therefore important for both surveillance purposes and in gauging the effectiveness of public health interventions.

Although there are a variety of physical activity assessment methods which have been used in pediatric populations, the pedometer remains a popular measurement tool. This is principally because pedometers provide an inexpensive, but objective, means to quantify the volume of physical activity undertaken in a given period (Laurson et al., 2008). They can be particularly useful in children due to their ease of use and ease of data interpretation for young people (Eston et al., 1998). Pedometry has also been effectively used in child-based physical activity interventions by utilising step counts as an open loop feedback tool (Lubans et al., 2009). The widespread use of pedometers with children has resulted in considerable data pertaining to the physical activity levels of children worldwide (Loucaides et al., 2003; Craig et al., 2010; Duncan et al., 2006). A recent review of pedometer use in children and adolescents concluded that they are valid measurement tools to assess ambulatory physical activity in children but that researchers need to include both weekday and weekend measures to accurately quantify physical activity (Clemes and Biddle, 2013).

A number of researchers have also attempted to classify children as being active/not active based on meeting a particular step/day count (Eisenmann et al., 2007; Duncan et al., 2007). However, there is currently no consensus on pedometer steps/day recommendations for children and adolescents. The two most commonly used cut-offs for steps/day also differ. Vincent and Pangrazi (2002) suggested a cut-off of 11,000 and 13,000 steps/day in girls and boys respectively, based on a normative approach. Conversely, Tudor-Locke et al (2004) proposed cut-offs of 12,000 and 15,000 steps/day for girls and boys respectively based on a large international sample and using receiver operating curve (ROC) analysis. However, Laurson et al (2008) used ROC analysis on a sample of children from Midwestern communities in the United States and suggested that lowering the values for current steps/day cutpoints may actually increase the accuracy of physical activity monitoring for children. Data have consistently suggested that large proportions of children do not meet these current pedometer recommendations (Laurson et al., 2008; Duncan et al., 2007; Craig et al., 2010). There have also been suggestions that researchers should select cut-points based on the preferred context of application (Laurson et al., 2008). Moreover, it is also common practice to report the proportion of boys and girls meeting these cut-off points separately (Clemes and Biddle, 2013). Other categorisation variables have also been employed including age, school year or BMI category (Clemes and Biddle, 2013). Ethnic differences have also been identified in the literature (Duncan et al., 2012; Johnson et al., 2010) with a recent review suggesting that it may be important to report step/counts by ethnicity (Clemes and Biddle, 2013).

In the context of the UK, this may be particularly important. Children from South Asian backgrounds have been identified as participating in lower levels of physical activity compared to their white peers (Eyre et al., 2013; Duncan et al., 2012; Owen et al., 2009). The BMI-adiposity relationship also differs for South Asian children compared to Whites (Nightingale et al., 2011). Thus, the use of generic BMI based cut-points to identify the proportion of children undertaking sufficient PA for healthy weight (e.g., Tudor-Locke et al., 2004) may not be appropriate. It would therefore seem meritous to examine whether these cut-points apply equally to different ethnic groups.

Therefore, this study sought to: (1) evaluate previously described steps/day cut-points in a sample of White and South Asian British primary school children and (2) use ROC analysis to generate alternative, ethnic specific, steps/day cut-offs for White and South Asian children.

Methods

Sample

Eight hundred and fifty one (356 boys and 406 girls) children from 5 primary schools in Coventry, Central England volunteered and returned signed parental informed consent forms to participate in the study. Children were from school years 4, 5 and 6 (aged 8-11years). The mean age ± SD of the children was 9.4 ± 1.1 years. All participating schools were located in the same geographical area of Central England and all offered the same number of physical education hours per week. The study took place during 2013. The schools were drawn from 5 electoral wards within the city of Coventry representing the spread of household income across the city. Of the children participating, 22.5% (n= 190) were from South Asian ethnic minority groups

(Indian, Pakistani, Bangladeshi), 73.4% (n = 625) from White ethnic groups, 3.8% (n =33) from black ethnic groups and 0.3% (n = 2) from Chinese ethnic groups based on the 2001 Census classification. Data relating to black and Chinese ethnic groups was subsequently removed from further analysis. Ethnicity data were determined via parental self-report when providing informed consent to participate. The study was approved by institutional ethics committee.

Procedures

Anthropometry

Stature and body mass were measured, to the nearest millimetre and 0.1kg respectively, using a Seca Stadiometre and weighing scales (Seca Instruments, Hamburg, Germany). Children were bare foot and lightly dressed for assessment. BMI was determined as kg/m^2. Children were subsequently classified as normal weight or overweight/obese based on IOTF cut-points (Cole et al., 2000).

Physical Activity

Habitual, free-living physical activity was assessed using sealed pedometry (NL-2000, New Lifestyles inc, USA) worn for 4 days (2 weekdays, 2 weekends) in a randomised order. This piezo-electric pedometer has been found to be reliable and valid as a measure of ambulatory activity (Crouter et al., 2005). This duration of monitoring, and including weekend days, has also been suggested as representative of habitual physical activity (Corder et al., 2008). Accuracy of the pedometers was also determined by the researchers prior to administration using the shaker test and 10-step test, congruent with prior studies (Laursen et al., 2008). Participants (and parents) were given instructions on wearing the pedometer prior to data collection. Daily step counts were stored in the internal memory of each pedometer enabling recall of each day's step count on collection of each pedometer. Across the period of measurement, the children were asked to complete a brief survey to verify that the pedometers were worn for the entire time of the study and indicating the nature of physical activity undertaken during the wear period. Where step counts were less than 1000 steps/day, data were excluded in line with the use of pedometers to assess PA in children and youth (Clemes and Biddle, 2013). As it is also important to account for potential bias between weekday and weekend step counts (Duncan et al., 2006) only participants who had 4 days of completed pedometer data where the pedometer was worn for at least 10h (Laurson et al., 2008) were included in analysis. From the total sample of participants, 763 children (86%) met the inclusion criteria while having complete anthropometric data. Missing activity data due to noncompliance were random, with no trends by gender, age, ethnic group of BMI. The proportion of children achieving the commonly used Vincent and Pangrazi (2002) and Tudor-Locke et al (2004) cut points were subsequently calculated from this data. All analyses were therefore conducted on a sample of 357 boys and 406 girls from White (n = 593) and South Asian (n = 170) ethic groups.

Statistical Analysis

Descriptive statistics were calculated by sex and ethnicity for the total sample. A series of 2 (Meeting/not meeting PA cut-off) X 2 (gender) ways analysis of covariance, controlling for age, were used to examine any differences in BMI. Analysis was conducted for White and South Asian groups separately and was also conducted using both the Vincent and Pangrazi (2002) and Tudor-Locke et al (2004) cut-points for steps/day. The use of ANCOVA in the analysis also enables any differences in BMI between children meeting/not meeting steps/day cut-points to be analyzed controlling for any impact of age whilst at the same time enabling the association between the dependant variable (BMI) and the covariate to be determined (Field, 2009). Where any significant differences were detected, Bonferroni post-hoc multiple comparisons were used to determine where differences lay.

Following this, ROC analysis was completed separately by sex and ethnic group to assess whether steps/day could discriminate between healthy and overweight/obesity status. The steps/day threshold or cut-point for each model was defined as the coordinate that had the closest value to 1 for the difference between the true positive (sensitivity) and the false positive (specificity) values. The area under the curve (AUC) was employed as a measure of the global accuracy of the cut-off values (Grenier et al., 2006). Once the ROC analysis had been completed, the thresholds generated were applied to the same BMI data that had been used to examine the efficacy of the Vincent and Pangrazi (2002) and Tudor-Locke et al (2004) thresholds. Statistical significance was set at P = .005, partial η^2 ($P\eta^2$) was used as a measure of effect size and the Statistical Package for Social Sciences (SPSS, Version 20, IBM inc, Chicago, ILL) was used for all analysis.

Results

When the proportion of children were classified in relation to international cut-points for overweight and obesity status, 79% of boys were classified as normal weight and

21% as overweight/obese. This is compared to girls where 66% were classified as normal weight and 34% as overweight/obese. In White children, 74% were normal weight and 26% overweight/obese. This is compared to 66% normal weight and 34% overweight/obese in South Asian children. Descriptive data showing average steps/day for gender, ethnic and weight status groups are presented in Table 1.

Table 1 about here **

Cross validation of the Vincent and Pangrazi (2002) and Tudor-Locke et al (2004) Cut-points

In White children, the results from ANCOVA indicated significant main effects for gender (F 1, 589 = 18.4, P = .0001, $P\eta^2$ = .03) and for the Vincent and Pangrazi cut-points (F 1, 589 = 34.4, P = .006, $P\eta^2$ = .013). BMI values were significantly lower in boys compared to girls (Mean diff = 1.138, P = .03) and in children who met the steps/day cut off compared to those that did not (Mean diff = .730, P = .013). Mean ± SE of BMI was 17.2 ± .19 and 18.4 ± .18 kg/m^2 for boys and girls and 17.4 ± .19 and 18.1 ± .18 kg/m^2 for children who met and did not meet the Vincent and Pangrazi (2002) cut-points respectively. Age was also significant as a covariate in this analysis (P = .0001, β = .706) with the whole model accounting for 8% of the variance in BMI (Adjusted R^2 = .08).

When the Tudor-Locke et al (2004) cut-points were considered in White children, there was also a significant main effect for gender (F 1,589 = 18.682, P = .0001, $P\eta^2$ = .031) and for the Tudor-Locke et al cut-points (F 1, 589 = 6.669, P =

.01, $P\eta^2$ = .011). Mean ± SE of BMI was 17.1 ± .21 and 18.3 ± .18 kg/m^2 for boys and girls and 17.3 ± .23 and 18.1 ± .16 kg/m^2 for children who met and did not meet the Tudor-Locke et al (2004) cut-points respectively. Age was not significant as a covariate (P = .07). The model accounted for 7.9% of the variation in BMI (Adjusted R^2 = .079).

When applied to South Asian children there was a significant main effect for the Vincent and Pangrazi cut-points (F 1, 165 = 4.310, P .039, $P\eta^2$ = .025) and age was significant as a covariate (P = .001, β = 1.015). In this instance, the mean ± SE of BMI was 17.3 ± .63 and 18.8 ± .33 kg/m^2 for children who met and did not meet the Vincent and Pangrazi (2002) cut-points respectively. This model accounted for 7.8% of the variance in BMI (Adjusted R^2 = .078). However, when the Tudor-Locke et al cut-points were considered, there were no significant main effects (all P <.05) for South Asian children.

In all cases there were no significant higher order interactions (P <.05).

ROC analysis to determine alternative steps/day cut-points in white and south Asian children.

When ROC analysis was applied to our sample of British White and South Asian boys and girls, the area under the curve (AUC) was significant for white boys (AUC = .641, P = .007, 95% CIs: .554-.709), White girls (AUC = .606, P = .04, 95% CIs: .524-.643), South Asian boys (AUC = .694, P = .006, 95% CIs: .588-.830) and South Asian girls (AUC = .7, P = .002, 95% CIs: .594-.815). Subsequent cut-points associated with healthy weight, when translated to steps/day were 13,625 for White boys, 13,135 for White girls, 10,897 for South Asian boys and 10,161 for South Asian girls. When these new cut-points were applied to BMI data for White children, there was a significant main effects for gender (F 1, 589 = 14.5, P = .0001, $P\eta^2$ =.024). Mean ± SE of BMI was 17.1 ± .19 and 18.1 ± .18 kg/m^2 for boys and girls. There was also a significant main effect for the new cut-points (F 1, 589 = 13.9, P = .0001, $P\eta^2$ = .023). Age was significant as a covariate (P = .0001, β = .718) and the model accounted for 9% of the variation in BMI (Adjusted R^2 = .09) in White children. For South Asian children, there was no main effect for gender (P = .138) but there was a significant main effect for those children who met/did not meet the new cut-point (F 1, 165 = 6.765, P = .01, $P\eta^2$ = .039). Within this model age was significant as a covariate (P = .0001, β = 1.029) and the model explained 9.1% of the variance in BMI for South Asian children (Adjusted R^2 = .091). Mean ± S.E. of BMI for White and South Asian children who were classified as meeting/not meeting the Vincent and Pangrazi (2002), Tudor-Locke et al (2004) and newly generated steps/day thresholds are presented in Figure 1a and b respectively.

Figure 1 about here

Discussion

The aims of this study were to: (1) evaluate previously described steps/day cut-points in a sample of White and South Asian British primary school children and (2) use ROC analysis to generate alternative, ethnic specific, steps/day cut-offs for White and South Asian children. The results of this study extend the current body of knowledge in relation to children's ambulatory physical activity and overweight status. The present study suggests that a large proportion of the sample did not meet current pedometer cut-points relating to physical activity for health benefit. The proportion not meeting these cut-offs was greater in South Asian compared to White children. Such an observation is supportive of prior research (Clemes and Biddle, 2013) although few studies have reported this in the context of South Asian children. When the criterion-referenced validity of the Vincent and Pangrazi (2002) and Tudor-Locke et al (2004) cut-points were examined in our sample of White and South Asian children, the Vincent and Pangrazi (2002) cut-points were effective in discriminating between normal weight and overweight/obesity in White and South Asian children. Conversely, when the Tudor-Locke et al (2004) cut-points were considered they significantly discriminated between normal weight and overweight/obesity in White children but not South Asian children. Thus, these cut-points would seem poorly placed to distinguish between weight status groups in British South Asian children. In some ways, this finding is not unexpected. The Tudor-Locke et al (2004) cut-points have evidenced poor criterion-referenced validity in prior research in American children (Laurson et al., 2008). This has been principally explained due to the large international sample employed by Tudor-Locke et al (2004) which included children from Sweden and Australia. Children in this study from both of these countries evidenced higher levels of physical activity than those previously reported for British children (Duncan et al., 2007). South Asian children have also been reported to be the least physically active ethnic group in Britain (Duncan et al., 2012; Eyre et al., 2013). Therefore, the Tudor-Locke et al (2004) cut-points likely reflect the higher steps/day values of Swedish and Australian children and hence did not perform well in this British sample.

From a practical perspective, pedometer cut-points where large proportions of children do not achieve these may be frustrating. This is particularly for normal weight children, where not meeting the recommendations may lead to a lack of motivation to continue in physical activity. Furthermore, a dose-response relationship between steps/day and BMI has been demonstrated (Eisenmann et al., 2007). However, caution is needed when prescribing cut-points to ensure that they are attainable by a target population (Laurson et al., 2008). This is the case when dealing with multi-ethnic samples where there is known variation in the physical activity levels as a consequence of ethnicity. It is also unlikely that if a child is already meeting a steps/day recommendation, they would reduce their habitual physical activity as a result.

Consequently, ROC analysis was used to identify criterion-referenced steps/day cut points for White and South Asian children in the current sample. These analyses identified different steps/day cut offs for white boys and girls compared to South Asian boys and girls with the cut-off associated with normal weight being approximately 3,000 steps/day lower for South Asian children compared to White children. This difference is commensurate with the lower levels of physical activity previously reported in South Asian children when compared to White children in Britain (Eyre et al., 2013; Duncan et al., 2012). The ROC-optimized cut-points are those which provide the maximal accuracy in distinguishing between normal weight and overweight/obesity in the present sample. To our knowledge the current results are the first to present ethnic specific cut-points for White and South Asian children in the UK. However, the lower cut-points for South Asian children should not be taken as a means to suggest South Asian children need to do less physical activity than their White peers. Rather, the cut-points may best be considered as a means to identify those at greater risk for overweight/obesity based on ambulatory physical activity. Similar ethnic differences have been reported (Duncan et al., 2012) and have been postulated to be a result of different lifestyle habits between White and South Asian groups in the UK (Rai and Finch, 1997).

However, it is also possible that the different BMI-adiposity relationship in South Asian children compared to White children might also partly explain the lower cut-points in South Asian compared to White children in the current study. BMI was used as a measure of weight status in the present study as this is the recommended means to classify weight status in UK children (Gatineau and Mathrani, 2011) and internationally (Cole, 2000). Despite this, prior work has suggested that BMI may underestimate adiposity in South Asian populations (Deurenberg et al., 2002; Shaw et al., 2007), with recent data suggesting that there is a tendency for higher levels of fatness at a given BMI in South Asian children compared to Whites (Nightingale et al., 2011). This point needs to be considered in future research and examining steps/day values based on adiposity may be better placed for developing ethnic specific cut-points in UK populations. As body composition data were not available in our sample this could not be completed in the present study. In addition, the Cole et al (2000) cut-points for defining overweight were employed in the present study on the basis that these are recommended by the International Obesity Task Force and are child specific. There are also no current child-specific BMI cut-offs for overweight/obesity relating to South Asian children. Given the aforementioned issues relating to BMI and body fatness in South Asian children and the WHO (2004) consultation statement identifying a need for differing BMI cut-points to define overweight/obesity in South Asian adults, further work identifying ethnic specific BMI cut-points for overweight and obesity in children is needed to better understand the association between weight status and other health indices in this population. Furthermore, the sample of South Asian children to White children in the present sample was relatively small which to some extent limits the scope of conclusions that might be made from this study. However, the sample in the present study in this respect is not dissimilar to other studies examining differences in White and South Asian groups (Eyre et al., 2013; Owen et al., 2009) and is representative of the White to South Asian split of the city within England from which the sample was drawn (Office of National Statistics, 2011).

It can however be argued that the comparisons between the Vincent and Pangrazi (2002), Tudor-Locke et al (2004) and newly generated thresholds are biased in favour of the thresholds generated in this study as a consequence of the statistical phenomenon of shrinkage. Shrinkage is associated with the quality of fit with a regression model and, common with any other research using similar techniques it is possible that the results presented here are biased as any such fitness thresholds will perform best on the sample it was derived from. Consequently, it is important for future research to cross validate the steps/day cut-points presented in this study using an independent sample of children other than that used in this study. It is also important to note that Tudor-Locke et al (2011) presented a revised analysis of step count cut-points for children, noting that 60minutes of moderate to vigorous physical activity daily appears to be achieved with a total value of 13,000 to 15,000 steps/day in boys and 11,000 to 12,000 steps/day in girls. The two previously validated cut-points examined in the present study fall within these recommendations and would therefore appear to remain useful as guidelines for total volume of physical activity in children generally.

The results of this study do however agree with conclusions made previously (Laurson et al., 2008) that cut-points generated from ambulatory physical activity data may have potential to be used for identification of children who may be at risk of unhealthy weight status based on BMI. The major novel findings of this study are the generation of ethnic specific thresholds based on ROC analysis which effectively distinguishes British schoolchildren based on pedometer determined physical activity. Such thresholds may therefore be useful in public health, medical and physical education settings to inform intervention targeting and risk identification.

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